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**CHARACTERISTICS AND SAMPLING EFFICIENCY  
OF PHTLAAS™ AIR SAMPLER**

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13. ABSTRACT (Maximum 200 words)  This study was conducted to characterize three configurations of Portable High-Throughput Liquid-Absorption Air Sampler (PHTLAAS™) (Zaromb Research Corporation, Hinsdale, IL). This is a light-weight, high-volume sampler that has a wetted wall cyclone as the aerosol collector. Three configurations of the PHTLAAS™ were tested: (1) the cyclone with a slit opening off axis to the center of the cyclone without liquid recirculation, (2) the cyclone with a circular inlet opening off axis to the cyclone without liquid recirculation, and (3) the cyclone with a slit opening off axis to the center of the cyclone with a liquid recirculation to wet the cyclone walls continuously. The sampling efficiency of the PHTLAAS™ was determined by fluorometer analysis of sampled monodisperse fluorescent polystyrene latex microspheres and sodium fluorescein tagged oleic acid particles. Results show the collection efficiency is relatively high (>62% for 1 - 10 µm particles with a peak of 84% for 4 µm particles). The power consumption of the Configuration 3 sampler is 85.3 W during sampling.			
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## PREFACE

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# CHARACTERISTICS AND SAMPLING EFFICIENCY OF PHTLAAS™ AIR SAMPLER

## 1. INTRODUCTION

This study was conducted to characterize three configurations of Portable High-Throughput Liquid-Absorption Air sampler (PHTLAAS™) (Zaromb Research Corporation, Hinsdale, IL) that evolved over the years. All three configurations have a wetted wall cyclone as the collector. Configurations 1 and 3 have a slit air inlet to the cyclone and Configuration 2 has a circular air inlet to the cyclone. Configurations 1 and 2 do not have a liquid recirculation system. Configuration 3 has a liquid recirculation system that brings the liquid from the top to the bottom of the cyclone to wet the cyclone surfaces continuously.

The performance of an aerosol sampler is the product of the sampler's aspiration, transmission, and collection efficiencies. The aspiration efficiency of a sampler is the efficiency with which particles enter the sampler inlet; transmission efficiency is the efficiency with which the particles are transported to the collection point, and the collection efficiency is the efficiency with which particles are captured and retained by the sampling medium.

In this study, the samplers were tested in an environmentally controlled chamber at calm air conditions. To determine the sampling efficiency of the PHTLAAS™, monodisperse fluorescent polystyrene latex (PSL) microspheres and sodium fluorescein tagged oleic acid (fluorescent oleic acid) particles were used with fluorometer analysis.

## 2. METHODS

### 2.1. Chamber

The sampler characterization tests were conducted in a 70 m<sup>3</sup> bio-safety Level 1 chamber (Figure 1) that has ultra-violet lights to kill biological material. The temperature and humidity of the chamber can be set and maintained by a computer. A fan placed in the chamber mixes the aerosol before and/or during the experiment.

Air entering and exiting the chamber is filtered by HEPA filters to achieve very low particle concentrations in the chamber. The maximum amount of air flow that can be exhausted from the chamber is approximately 700 cubic ft/min ( $2 \times 10^4$  L/min) that rapidly reduces the aerosol concentration in the chamber. There is also a small recirculation system that removes air from the chamber, passes it through a HEPA filter, and delivers it back to the chamber. This system is useful when the aerosol concentration in the chamber needs to be reduced by a small amount.

### 2.2. Sampler

The PHTLAAS™ aerosol sampler is a portable, light-weight, high-volume sampler (Figure 2). It has a wetted wall cyclone for aerosol collection. The sampler is packaged in a suitcase with a handle for easy carrying. During sampling, the suitcase is placed on its side and opened as shown in Figure 3. An inside view of the sampler is shown in Figure 4.

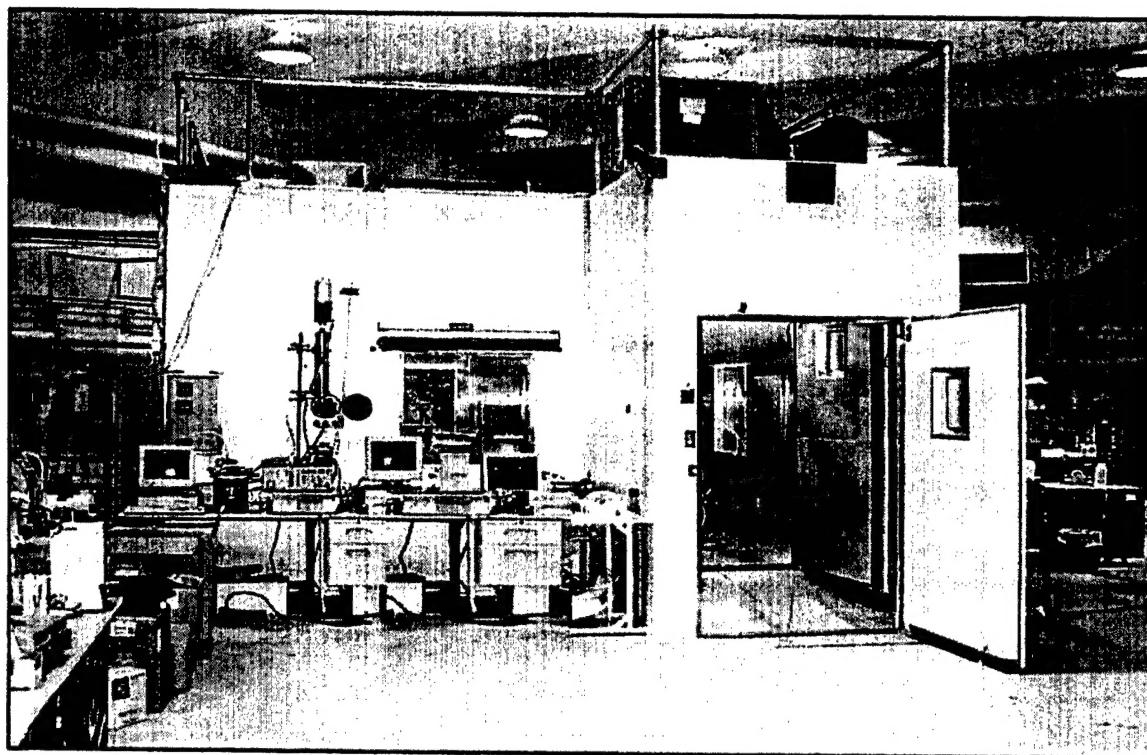


Figure 1.  $70\text{ m}^3$  Aerosol Chamber at the Edgewood Chemical Biological Center.

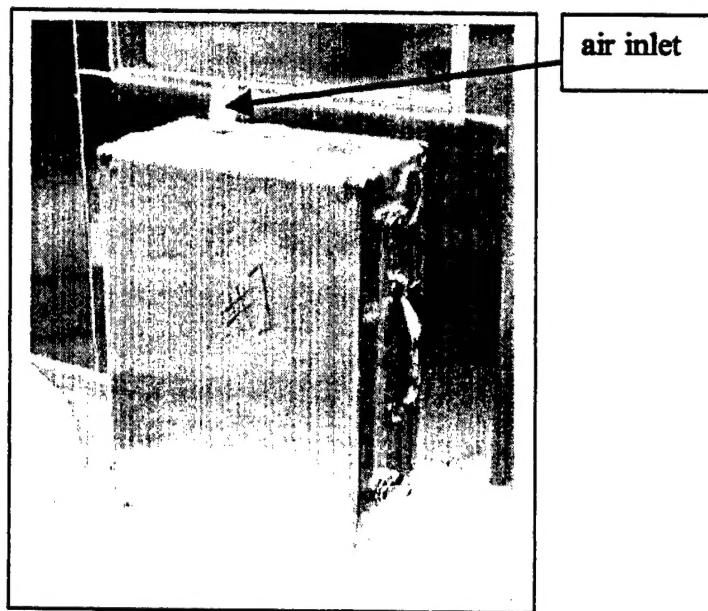


Figure 2. PHTLAAS™ air sampler.

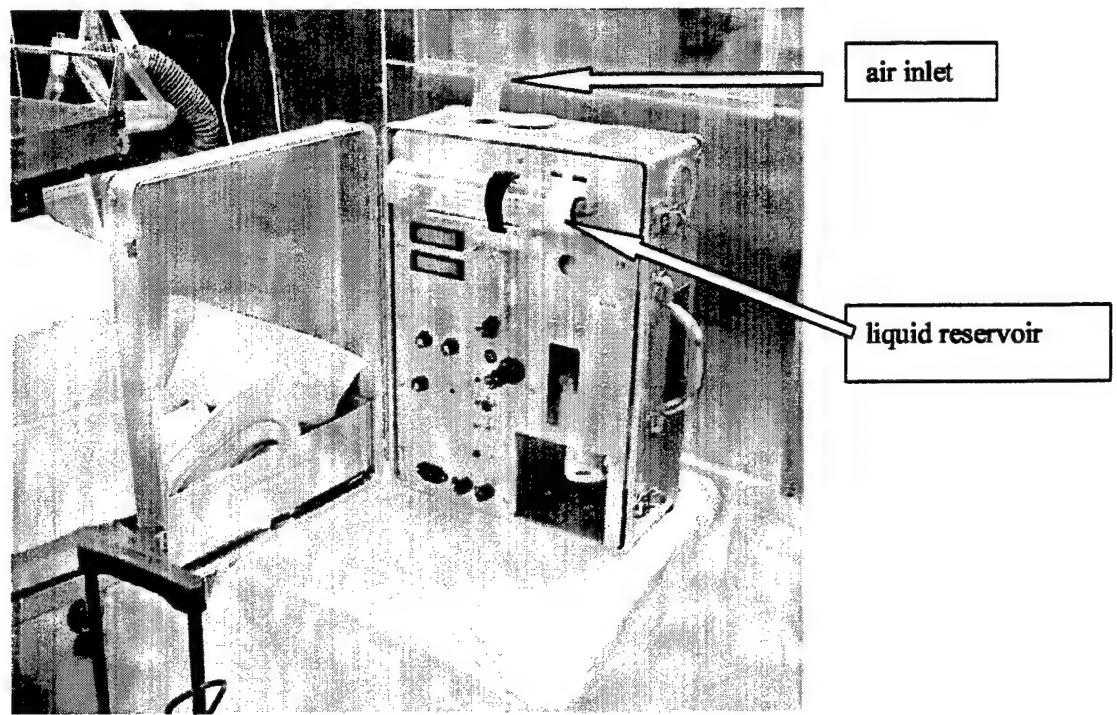


Figure 3. Inside front view (system controls) of PHTLAAS™ air sampler.

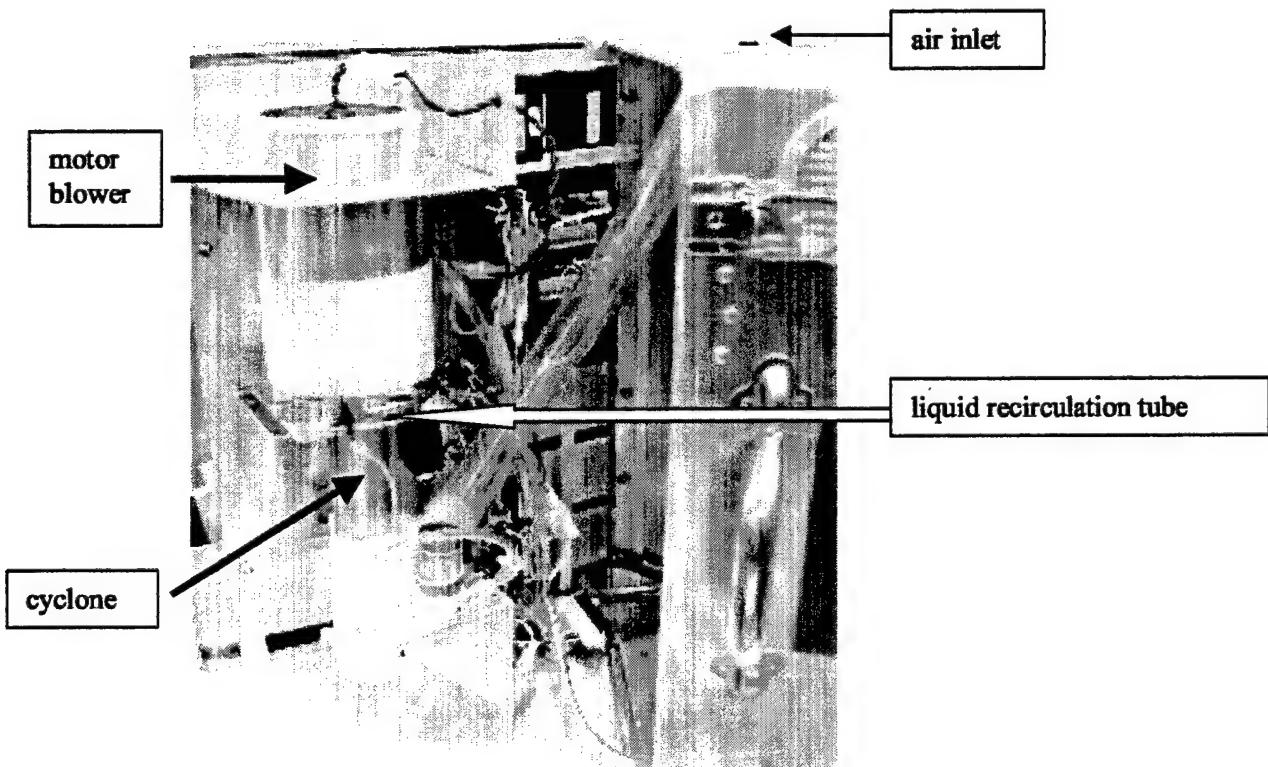


Figure 4. Inside back view of PHTLAAS™ air sampler.

The cyclone is a constant diameter cylindrical tube held vertically in the case during sampling. A motor blower on top of the cyclone pulls air in through the bottom of the cyclone. The air spirals through the cyclone and exits at the top. The air flow rate of the sampler can be adjusted to sample higher or lower air flow rates. An initial volume of liquid is added to the cyclone prior to sampling. The sampler can be set to slowly add liquid from the reservoir to compensate for liquid evaporation.

Three configurations of the sampler were tested: (1) the cyclone with a slit opening off axis to the center of the cyclone with no liquid recirculation, (2) the cyclone with a circular inlet opening off axis to the cyclone with no liquid recirculation, and (3) the cyclone with a slit opening off axis to the center of the cyclone with liquid recirculation to wet the cyclone walls continuously.

Overall dimensions and weight of the three configurations were approximately the same. The suitcase dimensions are approximately 46 cm (18") high, 36 cm (14") wide, and 21 cm (8") deep. The weight is approximately 9 kg (19.5 pounds). The power of the sampler (Configuration 3) was measured using a power analyzer (Extech Instruments, Taiwan). Air flow rates were measured using a Kurz flow meter (Kurz Instruments Incorporated, Monterey, CA).

Configuration 1: Cyclone with slit inlet and without liquid recirculation.

The first configuration had a slit inlet that was off axis to the cyclone without liquid recirculation. A middle of the range air flow rate of 260 L/min was used. During the test, air flow pulled the liquid to the top of the cyclone in the first 30 sec and held it there causing the cyclone walls to be dry during the sampling.

Configuration 2: Cyclone with circular inlet and without liquid recirculation.

This configuration had a circular inlet off axis to the cyclone without liquid recirculation. A picture of the cyclone is shown in Figure 5. Unlike the Configuration 1 tests, the air flow-rate was adjusted to keep the liquid in the middle of the cyclone to continuously wet the walls; 240 L/min.

Configuration 3: Cyclone with slit inlet and with liquid recirculation.

The third configuration had a slit inlet that was off axis to the cyclone with liquid recirculation to keep the cyclone walls continuously wetted. Figures 4 and 6 show the recirculation system. The recirculation provided excellent wetting of the cyclone walls during sampling. The maximum air flow rate of 317 L/min was used in this test.

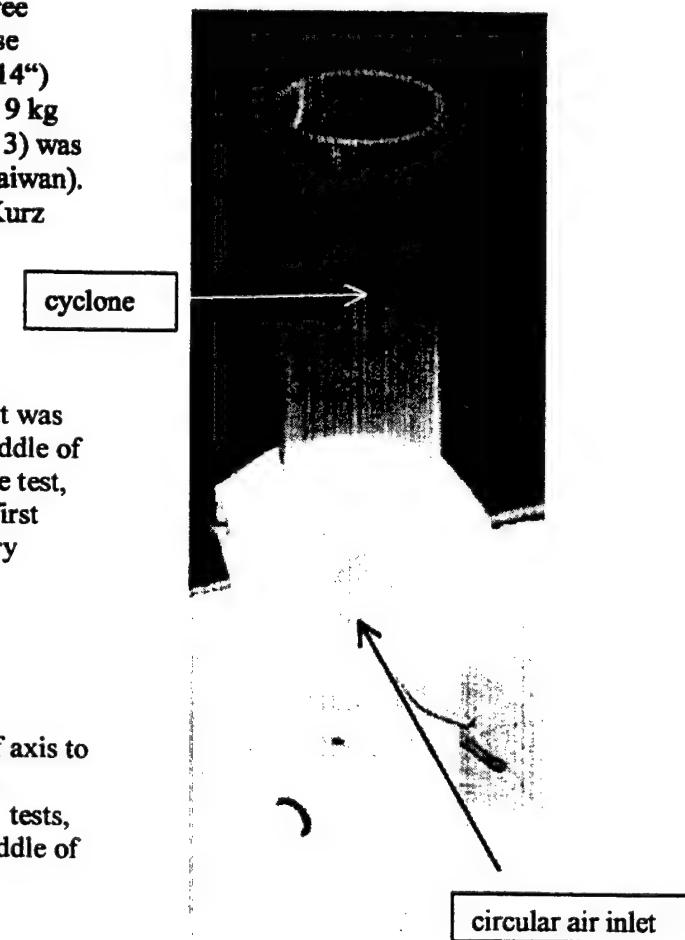


Figure 5. View of PHTLAAS™ cyclone showing circular inlet.

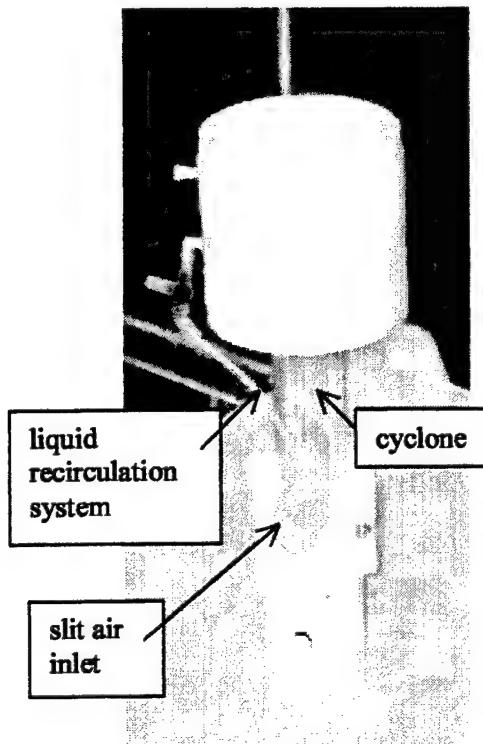


Figure 6. Configuration 3 liquid recirculation system.

The aerosol was generated and delivered to the test chamber for 10 min. Following that, air in the chamber was mixed for 1 min and sampling was conducted for 10 min. Four repeat tests were conducted with each particle size.

Particle size of fluorescent oleic acid was determined by sampling particles onto a Nybar coated microscope slide and measuring it using a microscope. The measured particle diameter was converted to an aerodynamic particle size using a spread factor (Olan-Figueroa et al., 1982) and the density of fluorescent oleic acid.

A microscopic picture of fluorescent oleic acid droplets on a slide is shown in Figure 7.

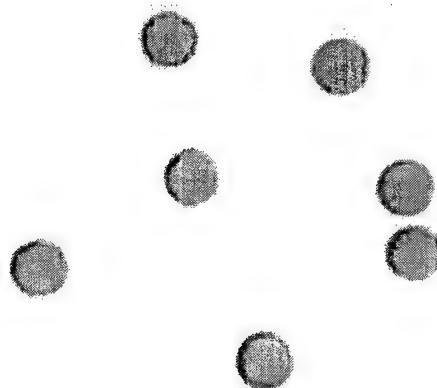


Figure 7. Microscopic picture of  $10 \mu\text{m}$  sodium fluorescein tagged oleic acid droplets.

## 2.4. Particle Sampling and Recovery

Glass fiber filters (Pall Corporation, Ann Arbor, MI) were used as reference filters for collecting fluorescent oleic acid particles. The samplers and reference filters sampled the air for approximately 10 min. The reference filters were removed from the filter holders, put into a fluorescein recovery solution, and shaken on a table rotator (Lab-Line Instruments, Incorporated, Melrose Park, IL) to recover the fluorescein from the filters into a solution. The fluorescence of the PHTLAAS™ and reference samples were measured using a fluorometer (Barnstead/Thermolyne, Dubuque, IA). The recovery solution used to remove the sodium fluorescein from the filters into liquid used filtered deionized water with a pH between 8 and 10 (obtained by adding a small amount of NH<sub>4</sub>OH: e.g., 500 mL of 2-propanol + 500 mL of water + 0.5625 mL of 14.8 N NH<sub>4</sub>OH). The method is described in detail by Kesavan et al. (2001).

Polycarbonate membrane filters were used as reference filters in the fluorescent PSL microsphere (beads) tests. Filters with PSL beads were placed into deionized water, vortexed, and hand shaken for 5 min as described in Kesavanathan and Doherty (1999) to transfer PSL beads from the filters into the liquid. The amount of fluorescence from the reference filters and PHTLAAS™ samples were measured using a fluorometer.

## 3. RESULTS

### 3.1. Configuration 1: Cyclone with slit inlet and no liquid recirculation

The sampling efficiencies at various particle sizes are shown in Table 1. The highest collection efficiency obtained was 15% for 6.7  $\mu\text{m}$  particles. Wash analyses of the six particle sizes show that the first wash solution had 45 – 73% of the fluorescent level of the sample; the second wash had 45 – 70 % of the fluorescent level of the sample; and the third wash had 3 – 57% of the fluorescent level of the sample.

Table 1. Configuration 1: PHTLAAS™ sampler characteristics and results for cyclone with slit inlet and without liquid recirculation.

Characteristic of PHTLAAS™	Results
Air sampling rate, L/min	260
Sampling time, minutes	10
Liquid volume input, mL	20
Particle Size ( $\mu\text{m}$ )	Sampling Efficiency (%)
1	1.1 $\pm$ 0.5
4.4	9.8 $\pm$ 6.6
5.8	10.1 $\pm$ 0.7
6.7	15.0 $\pm$ 2.0
11.1	11.1 $\pm$ 1.9
12.9	10.9 $\pm$ 0.7

## 3.2.

Configuration 2: Cyclone with circular inlet and no liquid recirculation

Sampling efficiency results are shown in Table 2. The highest sampling efficiency is 42.2% for 5  $\mu\text{m}$  particles. The wash analyses show that the first wash solution had 15.5% of the fluorescent level of the sample; the second wash solution had 2.1% of the fluorescent level of the sample; and the third wash solution had 0.7% of the fluorescent level of the sample.

Table 2. Configuration 2: Characteristics and results for cyclone with circular inlet and without liquid recirculation.

Characteristic of PHTLAAS™	Results
Air sampling rate, L/min	240
Sampling time, minutes	10
Liquid volume input, cc	20
Particle Size ( $\mu\text{m}$ )	Sampling efficiency (%)
1	4.6 $\pm$ 2.6
3.5	19.0 $\pm$ 4.7
5.0	42.2 $\pm$ 1.4
10.5	36.2 $\pm$ 4.7

## 3.3.

Configuration 3: Cyclone with slit inlet and liquid recirculation

The PHTLAAS™ sampling efficiency at various particle sizes is shown in Figure 8 and Table 3. Sampling efficiencies varied between 62% and 84% for 1 to 10  $\mu\text{m}$  particle sizes, with the highest efficiency at 84% for the 4  $\mu\text{m}$  particles.

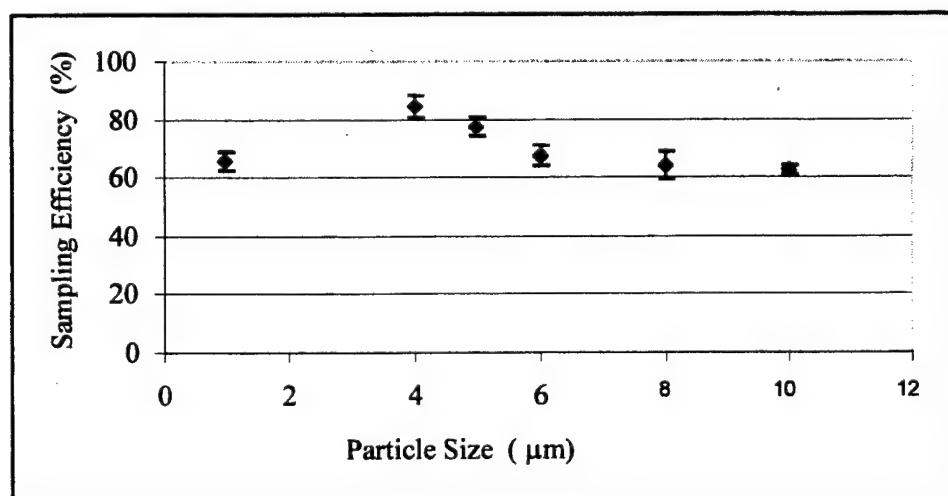


Figure 8. PHTLAAS™ sampling efficiency for Configuration 3.

**Table 3. Configuration 3: Characteristics and results for cyclone with slit inlet and with liquid recirculation.**

Characteristic of PHTLAAS™	Results
Air sampling rate, L/min	317
Sampling time, minutes	10
Liquid volume input, mL	50
Average liquid volume output ( $\pm$ std dev), mL	$35.3 \pm 3.5$
Power, Watts	85.3
Voltage, Volts	123.6
Current, Amps	1.1
<u>Particle Size (μm)</u>	<u>Sampling Efficiency (%)</u>
1	$65.7 \pm 3.0$
4	$84.3 \pm 4.2$
6	$67.5 \pm 3.7$
8	$64.3 \pm 4.6$
10	$62.5 \pm 1.9$

#### 4. CONCLUSIONS

This study determined the sampler characteristics and sampling efficiency of the Portable High-Throughput Liquid-Absorption Air sampler (PHTLAAS™) portable air sampler at three developmental stages. Configurations 1 and 3 have a slit air inlet to the cyclone, and Configuration 2 has a circular air inlet to the cyclone. Configurations 1 and 2 do not have a liquid recirculation system, however, Configuration 3 has a liquid recirculation system that brings the liquid from the top to the bottom of the cyclone, keeping cyclone surfaces continuously wet. Results show how the sampler evolved and improved in collection efficiency. Configurations 1 and 2 had lower sampling efficiencies than Configuration 3, which had a peak of 84.3% for 4 micron particles. The results showed that three washes were adequate for the removal of sodium fluorescein and polystyrene latex microspheres from the cyclone in Configurations 2 and 3. In Configuration 1, however, there was a significant amount of fluorescence in wash 3 liquid due to the inadequate wetting and washing of the walls. The air flow rate of the sampler can be adjusted easily. The power used by the sampler in Configuration 3 is 85.3 W, which is lower than many other samplers.

PHTLAAS™ Configuration 1 tests showed that the air flow rate of 260 Lpm pulled the liquid up to the top of the cyclone in less than 30 sec, and the liquid was not available for wetting the cyclone walls during the remainder of sampling. Therefore, in the PHTLAAS™ Configuration 2 tests, the air flow rate was adjusted to 240 Lpm, keeping the liquid in the middle of the cyclone and wetting the walls. Configuration 3 had a liquid recirculation carrying the liquid from the top to the bottom of the cyclone, therefore, the highest air flow rate of 317 Lpm was used to achieve the highest sampling efficiency.

Currently the PHTLAAS™ requires an operator to prime the recirculation system. Alternatively, a pump could be installed to recirculate the liquid back to the bottom of the cyclone. A reservoir is available to use to compensate for evaporation if a longer sampling duration is required; the sampler can be set to add liquid from the reservoir to the cyclone.

As recommended by the sampler developer, 20 cc of liquid was used with Configuration 1 and 2 tests, and 50 cc of liquid was used with Configuration 3 tests. The sampler developer also recommended a liquid volume of 30 cc be used with Configuration 3 to achieve concentrated samples. However, the user needs to ensure the cyclone walls are completely wetted during the sampling with 30 cc of liquid.

The inlet is a flexible tube that reaches out of the case at an angle. The inlet could be improved by using a unidirectional inlet with a rain cap, attached to the case. This would result in a vertical inlet. A screen would also be useful in preventing large objects and bugs from entering the sampler.

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